What’s Different for EUV masks?

GLOBALFOUNDRIES – Tom Faure, Jed Rankin
EUV Benefits GLOBALFOUNDRIES 7nm

Multiple Fab Benefits:

- **Lithographic Performance**
  - Device performance
- **Wafer Cycle Time**
  - Faster Development
  - Faster Prototyping
  - Faster Production

7nm Cycle Time Impact:

- ~60 day reduction in development
- ~31 day reduction in production
- **Larger benefit at 5nm node with ~20% more 193 levels required for optical-only solution**

193 Multipatterning  
EUV Single-exposure  
Samsung, VLSI 2017
# 7nm EUV vs. Optical Mask comparison

## Physical Design Differences:

<table>
<thead>
<tr>
<th></th>
<th>7nm Optical</th>
<th>7nm EUV</th>
<th>5nm EUV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contacts / Vias</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Masks per layer</td>
<td>2-4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tone</td>
<td>CP</td>
<td>CN</td>
<td>CN</td>
</tr>
<tr>
<td>Primary Feature size on Mask (4x)</td>
<td>250nm</td>
<td>70nm</td>
<td>55nm</td>
</tr>
<tr>
<td>SRAFs (4X)</td>
<td>50-60nm opaque</td>
<td>None *</td>
<td>30nm clear</td>
</tr>
<tr>
<td><strong>Cuts / Metals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Masks</td>
<td>3</td>
<td>1</td>
<td>1-2*</td>
</tr>
<tr>
<td>Tone</td>
<td>CP/CN</td>
<td>CN</td>
<td>CN + CP</td>
</tr>
<tr>
<td>Minimum Feature size on Mask (4x)</td>
<td>200nm</td>
<td>50 nm</td>
<td>45nm</td>
</tr>
<tr>
<td>SRAFs</td>
<td>54nm opaque 60nm clear</td>
<td>None</td>
<td>24nm clear 30nm opaque</td>
</tr>
</tbody>
</table>

**EUV allows design relaxation to Circa 32/28 nm**

- Bidirectional Metals Allowed
- Relaxed local density (minimum SRAF)
- Simplified OPC (still requires MBOPC)

→ *ILT not needed for 7nm EUV, but may be used*
Unique EUV mask requirements → MBMW
Benefit for 7nm, required for 5nm

**Performance**
- Resolution (40nm → 24nm)
- Line Edge Roughness (4nm → 2nm)
- Local CDU (2.5nm → 1.5nm)
- Image Placement (2.5nm → 1.5nm)

**Design**
- Shot Count (ILT)
- Data Density (SRAF)

Low Sensitivity Resists
Multibeam Writer
Long Write Times

MBMW tools originally developed with expectations of high shot-count and data density

EUV allows relaxation of shot/vertex density → Initial EUV layers will have no SRAF, less fill, no PRAF
CA Mask Comparison

EUV CA: PCAR
4.9% Open Area

Opt CA-1: NCAR
90% Open Area

Opt CA-2: NCAR
92% Open Area

Opt CA-3: NCAR
91% Open Area

Opt CA-4: NCAR
85% Open Area

Optical Mask Design

EUV Mask Design
M1 Mask Comparison

EUV M1: PCAR (PTD)
49% Open Area

Opt M1-1: NCAR (NTD)
45% Open Area

Opt M1-2: NCAR
74% Open Area

Opt M1-3: NCAR
69% Open Area

Optical Mask Design

EUV Mask Design
EUV Specific Mask Challenges

Materials & Structure:
- Importance of Blank defects (mirror)
- Introduction of Ta and Ru for RIE & repair
- Black-Border & Out-Of-Band suppression
- Backside and Cleanliness
- Flatness & Thickness requirements
- Lack of Pellicle at HVM introduction
- New (Thinner) absorbers (post 7nm)
  → repair, integration and durability challenges

Equipment
- MBMW for CD, I/P, LER LCDU performance
- Use of Non-actinic inspection (DUV or SEM)
- Limited AIMS availability (lead time)
- Anamorphic Scaling (timing= beyond 5 nm)
  → minimal impact expected (handled during fracture)
- Equipment extendability (Inspection, AIMS, writers, repair)
EUV Specific Mask Data Challenges

Current:
- Loss of Hierarchy / Jobdecking (Flare, Radial Azimuthal reflection)
- MPC (Dose modulation) for Resolution
- Blank Defectivity Management & Pattern-Shift for defect avoidance
- Unique e-beam corrections

Future:
- Data Density
- Fracture / prep for MBMW or advanced writers
  → Increased off-board correction (MPC, CD & I/P e-beam corrections)
- Migration toward ILT and curvilinear designs
  → Because we can (data and writers) not because it’s needed (yet)
Positional dependence within EUV field:
- EUV flare
- Radial exposure slit
- Reflective Mask

Unique Data challenges:
- Additional MDP complexity
  - Creation of Flare Map
  - Positional awareness (X-Y)
  - Requires concurrent data
- Loss of hierarchy
- No repeated die (jobdeck)
- Future - Anamorphic
Summary

• EUV is real:
  - Benefits are real: Imaging quality, Cycle Time
  - Challenges are real: Scanner-throughput, Mask-defectivity, EPE, Resist-stochastics

• Changes to Data Infrastructure and processing are required
  - OPC, MPC, Jobdecking, Pattern-shifting (defects), Image shifting, fracture, anamorphic scaling….

➡ Solutions exist.  Data will not limit EUV’s success.